Optimal Investment With Fixed Refinancing Costs

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Abstract

Case studies show that corporate managers seek financial independence to avoid interference by outside financiers. We incorporate this financial xenophobia as a fixed cost in a simple dynamic model of financing and investment. To avoid refinancing in the future, the firm alters its behavior depending on the extent of its financial xenophobia and the realization of a revenue shock. With a sufficiently adverse shock, the firm holds no liquidity. Otherwise, the firm precautionarily saves and holds both liquidity and external finance. Investment always responds to neoclassical fundamentals, but responds to cash flow only when the firm holds no liquidity.

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1 Introduction

Firms finance the vast majority of their capital expenditures internally rather than using external finance in the form of debt and equity. For example, between 1980 and 2000, US firms financed between 65 and 97 percent of investment expenditures using internal funds and the rest using external finance, mostly in the form of debt. Firms rely predominantly on internal funds in part by drawing on accumulated liquid resources. For example, in each year from 1980 to 1999, publicly-traded US firms held on average about one-year's worth of net cash flow as liquidity.[1]

In this paper we explore an intuitive reason why firms might hold liquidity and use it to finance investment, namely that managers put themselves in a vulnerable position when they go outside the firm to acquire new resources. There is substantial evidence to support this conjecture. According to Donaldson's (1984) case studies of top managers in large US corporations, one of management's overriding concerns is interference by outside financiers, a concern we call financial xenophobia. One executive of a Fortune 250 company summarized it this way: "The debt policy [of our company] reflects a primary emphasis on freedom — that if we maintain the debt limits we have set, we will be free from banking restrictions and the banks will not inhibit our activities." (p. 56) The financial strategy that emerges from management's desire for independence can best be characterized as one of self-sufficiency. When managers control their financing, the timing, magnitude, and form of investment remain theirs to decide. This imposes the need to live within financial limits:

> The wish to be independent and self-sufficient moderates the management's drive for maximum corporate growth by restricting the pool of available capital. For example, management may decide to forgo certain external sources of funds because they threaten to involve outsiders in resource-allocation decisions. Or it may fear to accept funds that seem likely to be withdrawn at a critical point in the firm's strategic development. Thus corporate managers trade off maximum economic scale for greater control of their resources and/or greater assurance that those resources will be loyal...These issues are central to management's strategic use of debt finance and they may apply to equity sources as well. (p. 24).

[1] We calculated the composition of financing from the Board of Governors of the Federal Reserve System, *Flow of Funds Accounts* (www.federalreserve.gov/releases/z1/Current/data.htm). We used Compustat data to calculate the measure of liquidity as the ratio of the sum of the stock of cash and short-term liquid investments and cash flow.

In practical terms this means that managers rely on internal funds whenever they can, supplemented by debt conservatively chosen to assure an arm's-length debtor-creditor relationship. Only as a last resort do managers use equity financing. As we have already mentioned, this financial pecking order is a well-established empirical regularity.[2]

From an agency-theoretic perspective it is natural to expect financial xenophobia: managers are self-interested, which gives them good reason to resent the limits to their control of corporate resources imposed by outside financiers. This is spelled out in Jensen's (1986) free cash flow theory, which argues that unfettered management will invest the firm's excess financial resources in projects that are not in the outsiders' best interest. While undoubtedly there is truth in this, we think this rather Hobbesian view of management has been overemphasized. A more balanced perspective recognizes that despite their conflict of interest, both managers and outside financiers contribute to the firm and share the overriding goal of assuring the business' vitality. The fundamental way in which the two parties differ is in how closely they are tied to the firm. To run the day-to-day operations of the firm, the manager has to invest in human capital that is specific to the firm. In contrast to the outsiders, who have a largely liquid investment, the manager's investment is sunk. In the absence of complete contracts, this personal commitment exposes the manager to a hold-up problem since outsiders may be able to expropriate the return from her investment. Thus, agency costs are likely to cut both ways: just as the manager can divert resources inside the firm from what the outsiders consider their best use, the opposite is true as well.

A rational response by the manager to this type of hold-up problem is to put less human capital into the firm. Therefore, to the extent that outsiders benefit from managerial initiative, interference decreases the value of the firm. Hence, we emphasize that there must be important benefits to granting the manager at least some control over corporate resources.[3] But contractual incompleteness is likely to prevent the use of explicit agreements that commit outsiders to leaving the manager alone. In this case, Burkart, Gromb, and Panunzi (1997) argue that the public-good nature of shareholder

[2]Myers and Majluf (1984) also generate this ranking of funds, but not the holding of liquidity, by assuming asymmetric information across the boundary of the firm. However, their explanation is fundamentally different from Donaldson's. In their model, the main conflict of interest is not between managers and outside financiers, but between new and old shareholders.

[3]For surveys of the literature on the costs and benefit of managerial discretion, see Allen and Gale (2000) and Shleifer and Vishny (1997).

activism allows a dispersed ownership structure to serve as a commitment device and to implement a balance of power between the manager and outsiders so that the firm can be run more efficiently (see also Acemoglu 1995 and Myers 2000). However, these everyday corporate control mechanisms may break down when the manager seeks additional external finance, since it then makes good sense for outsiders to increase their scrutiny of the firm. After all, on one hand, it may be good news that management needs additional funding for profitable investment projects. On the other, it may be bad news if management has failed to generate sufficient profits because it invested too much, too little, or simply unwisely. Hence, when managers are forced to turn to outsiders for new resources, they expose themselves to the risk of losing benefits from their past investment in the firm.[4]

We study how financially xenophobic managers make finance and investment decisions by assuming that they face a fixed cost of increasing external finance. This fixed cost is a simple way to capture the idea that seeking external finance can exacerbate the conflict of interest between managers and outsiders. We leave the formal modeling of the underlying hold-up problem between managers and outsiders for a separate investigation, focusing instead on its implications for the firm's financing and investment decisions.[5]

We find that financial xenophobia has remarkable effects on the firm's optimal investment and financing even in the absence of risk aversion, limited liability, irreversible physical capital, and differences in risk between physical capital and liquidity. Not surprisingly, the financial adjustment cost introduces the type of inertia in the firm's contemporaneous financing policy suggested by Donaldson: refinancing may not be undertaken even though an additional dollar could be profitably invested inside the firm. The more interesting effect comes from the specter of refinancing in the future. In order to avoid seeking new financing in the subsequent period, the firm changes its current behavior, both in terms of the total amount of resources held and in terms of

[4]One way to think about this argument is in terms of Myers' (1977) debt overhang model. In that model, creditors do not want to lend to the firm because their claims are subordinate to previous ones. Our interpretation of Donaldson's evidence is that managers do not want to take external finance because they know that their claims are subordinated to those of the outsiders. Essentially, this argument is the converse of Myers'.

[5]In this sense, our approach is similar to that taken in the literature on the consequences of managerial myopia, where it is assumed that managers care about the current share price (see, e.g., Brandenburger and Polak 1996 and Stein 1989).

their composition. These distortions depend on the level of the manager's financial xenophobia as well as on the realization of a revenue shock.

Firms that have experienced a sufficiently favorable shock do not repay external finance, instead they precautionarily save by accumulating idle liquidity. Greater financial xenophobia strengthens the incentive to hold idle liquidity. In contrast, firms that have experienced a sufficiently adverse shock hold no liquidity. They may, however, precautionarily save by overinvesting in capital.

While investment is always responsive to neoclassical fundamentals, it is affected by current cash flow only in some circumstances. When firms hold liquidity, cash has no effect on either the capital stock or external finance. When firms do not hold liquidity, their optimal choices of both investment and external finance respond to an additional dollar of cash, which is split between capital investment and the repayment of external finance.

The paper is organized as follows. In the next section we present the model. In sections three and four we solve the model first in the absence of, then in the presence of, financial xenophobia. In section five we discuss our findings and relate them to those in the literature. The final section concludes. The appendix contains the proofs of the propositions.

2 Model

We use a three-period model in which the manager chooses in each period the firm's capital stock, external finance, and liquidity holdings. This simplified dynamic framework admits an analytic solution, which is desirable since so little is known about the effects of financial xenophobia on financing and investment. We first derive the optimal decisions in the absence of financial xenophobia. In this benchmark, the manager acts in the interests of the owners by maximizing the expected discounted value of future profits. We then analyze how a manager who faces a fixed cost of refinancing runs the firm.

We make several assumptions to simplify the analysis and to focus on the issues that are material to our investigation. First, we assume that the manager is risk-neutral. It is important to highlight this assumption since the xenophobic manager's optimal decisions resemble in some ways those that would be made by a risk-averse manager. In particular, sometimes the manager will precautionarily save by accumulating internal resources despite her risk-neutrality. Second, we are primarily interested in the distinction between internal and external finance, not in the composition of external finance. We therefore assume only a single source of external finance. Third, the manager controls the firm's liquidity except for a variable cost of funds to service external finance. We make this assumption to focus the analysis on the manager's use of discretionary control over financial resources. We leave the exact delineation of that control until we better understand the simplest case.[6] Finally, we do not explicitly consider limited liability because its effects are relatively well understood.

2.1 Production Technology

Physical capital, K, is the sole factor of production. We normalize the price of output to unity and the price of investment is p. Revenue from production, $\Pi(K_t)$, is strictly increasing and strictly concave in capital and satisfies the Inada conditions. There is a stochastic revenue shock, z_t, which is additive and independently and identically distributed (iid) with a density function $f(z_t)$. As a result, cash flow from operations at time t is the sum of the shock z_t and revenue from production $\Pi(K_t)$. The additivity allows us to contrast the features of our model with a benchmark in which the shock has no effect on the optimal policy. While this representation might seem too restrictive, in fact, it makes our results all the more surprising: Firms hold cash even though they have access to a risk-free productive asset.

Capital evolves according to the accounting identity:

$$K_{t+1} = (1 - \delta)K_t + I_t,$$

where δ is the constant rate of economic depreciation, and I is investment. Apart from depreciation, investment in capital is completely reversible.

[6] If external finance is interpreted as equity, this assumption is tantamount to precluding any flexibility in dividend payments.

2.2 Financial Technology

A common view is that the source of financing affects investment decisions. This is captured in models in which there is asymmetric information between the firm's management and its outside financiers. In these models, external funds are more expensive at the margin than internal funds (see Hubbard 1998 for a survey). When investment opportunities require additional external finance, firms will underinvest because of the premium outsiders charge. Moreover, investment is liquidity-constrained in the sense that an extra dollar of cash relaxes the financing constraint, enabling more investment. We use this type of model as a baseline and augment it with financial xenophobia.

The firm can invest its liquid financial resources, L_t, and earn a rate of return of i. The discount factor is therefore $\beta = 1/(1+i)$. The firm also has access to external finance, D_t, at the cost $r(D_t)$. We assume that $r(D_t)$ is strictly increasing and strictly convex, reflecting the risk premium that outsiders charge the firm, and that $r(0) = i$. Moreover, to enable the firm to dynamically manage its financing we assume that external finance is long-term and does not have to be repaid after one period.

In the introduction we presented some evidence suggesting that managers face a cost when they get new financing. We model such financial xenophobia as a fixed cost of acquiring, but not retiring, external finance:

$$m(D_t, D_{t+1}) = \begin{cases} 0 & \text{if } D_{t+1} \leq D_t \\ \mu & \text{if } D_{t+1} > D_t. \end{cases}$$

More generally, this cost could depend on the size of the firm, its ability to repay, or even more ephemeral factors, such as management's reputation. While it might be interesting to extend our model in these directions, our simple function captures the key insight that we want to model.[7]

2.3 The Decision Problem

The timing of the decision problem is illustrated in figure 1. At the beginning of each period the firm inherits the state variables D_t, K_t, and L_t. The firm services its external

[7] Certain types of financing may well impose smaller costs on the manager than others. For example, short-term debt used to finance seasonal inventory fluctuations is likely to impose a small, or even negligible, fixed cost. We abstract away from this heterogeneity as well.

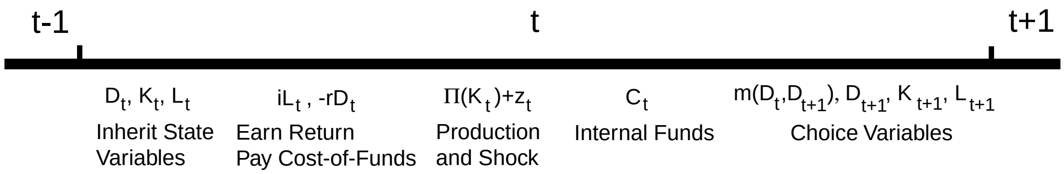

Figure 1: Timeline of the Decision Problem

finance, $r(D_t)D_t$, and receives interest from its liquid resources, iL_t. Production and the stochastic shock generate cash flow from operations, $\Pi(K_t)+z_t$. These financial and real activities plus the liquidation value of the surviving capital stock define the firm's internal funds, $C_t \equiv (1+i)L_t - r(D_t)D_t + \Pi(K_t) + z_t + p(1-\delta)K_t$. Finally, the manager chooses next period's stocks of external finance and capital, subject to the fixed cost μ, if applicable. Outgoing liquidity is a residual, defined as the sum of internal funds and new external finance, less the cost of investment:

$$L_{t+1} = C_t + D_{t+1} - D_t - pK_{t+1}. \tag{1}$$

The only exception is period 3, which closes with the liquidation of the firm.

The manager's decision problem is to solve

$$\begin{aligned} M(D_t, K_t, L_t) = \max_{\{K_{t+1}, D_{t+1}\}} &\{(1+i)L_t + \Pi(K_t) + z_t - p[K_{t+1} - (1-\delta)K_t] \\ &-[1+r(D_t)]D_t + D_{t+1} - m(D_t, D_{t+1}) + \beta \mathrm{E}_t M(D_{t+1}, K_{t+1}, L_{t+1})\} \end{aligned} \tag{2}$$

subject to

$$K_{t+1} \le p^{-1}(C_t + D_{t+1} - D_t) \tag{3}$$

$$D_{t+1} \ge 0. \tag{4}$$

The first constraint forces investment to be less than or equal to the amount of available resources, which could include new financing. The second constraint forces external finance to be non-negative.

3 Solution Without Financial Xenophobia

To establish a benchmark, we first characterize the optimal financing and investment decisions under the assumption that there is no financial xenophobia ($\mu = 0$). The optimal policy is to acquire or maintain external funds only to the extent that they can be profitably invested in physical capital. This policy is summarized in the following proposition:

Proposition 1: *The investment and financing decisions of the firm in any period can be characterized in terms of two regions of values of C_t.*

(1) When C_t is sufficiently small, the firm holds external finance, but no liquidity. The optimal capital stock and external finance are given jointly by the first constraint (equation (3)), which holds with equality, and the following marginal condition:

$$\Pi'(K^*_{t+1}) = p[r(D^*_{t+1}) + r'(D^*_{t+1})D^*_{t+1} + \delta].$$

(2) When C_t is sufficiently large, the firm holds liquidity, but no external finance. The optimal capital stock is implicitly defined by

$$\Pi'(K^*_{t+1}) = p(i + \delta).$$

The stock of liquidity is given as a residual by equation (1).

These optimality conditions are familiar: the optimal capital stock is determined by its marginal revenue product and by the cost of capital, which is a function of the price of capital, its depreciation rate, and the stock of external finance through the cost of funds. Since the cost of funds is strictly increasing in the amount of external finance, the optimal capital stock decreases with the firm's external finance.

We use figure 2 to illustrate the solution to the problem in terms of internal funds. Bad shocks reduce internal funds (labeled cash for shorthand), causing the cost-of-funds curve to shift to the left. In this situation, an extra dollar of cash is split between investment and paying down external finance. This is the sense in which investment is liquidity constrained. When the firm has enough internal funds to pay off completely its external finance, its cost-of-funds curve has shifted to the right so that the optimal

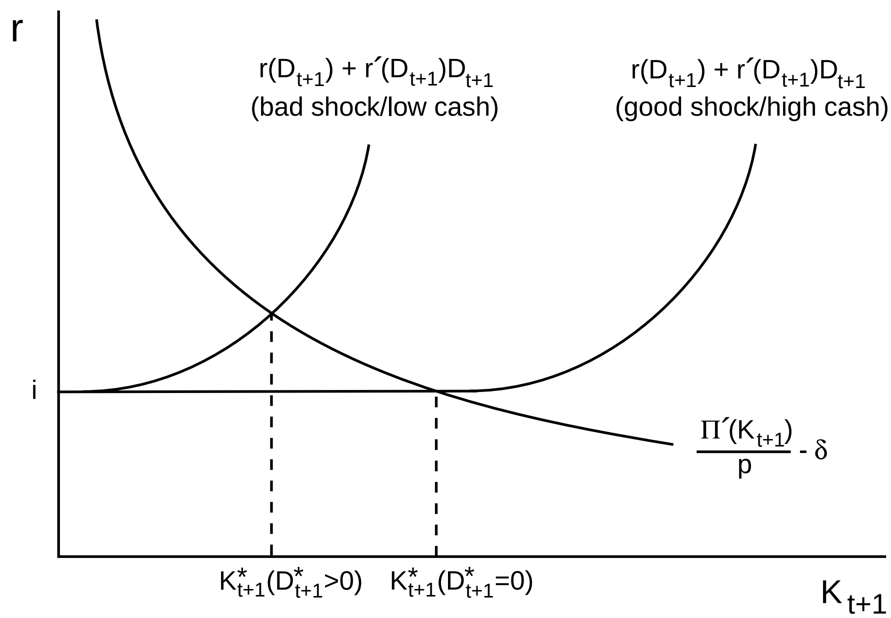

Figure 2: Optimal Investment and Financing Decisions Without Financial Xenophobia

capital stock is independent of internal funds. In this situation, an extra dollar of cash accumulates in the firm. But this accumulation is not a choice in any meaningful sense since liquidity is only a residual. In summary, absent financial xenophobia the firm never simultaneously maintains external finance and liquidity.

4 Solution With Financial Xenophobia

Consider next the case in which the manager is financially xenophobic ($\mu > 0$). We proceed by backward induction, starting with the solution for periods two and three, where decision-making is relatively simple to characterize, and then proceed to the first period.

4.1 Periods Two and Three

In the third period, the manager has no decision to make since the firm is exogenously forced into liquidation. There is no limited liability, so the entire liquidation value, be it positive or negative, enters the manager's payoff for period three. The liquidation value is equal to internal funds, C_3, minus external finance, D_3.

In the second period, the manager must weigh the discrete cost of getting new financing, $\mu > 0$, against the net benefit of doing so, which is determined by the capital stock, K_2, the stock of external finance, D_2, and the amount of internal funds, C_2. After the manager has incurred the fixed cost of refinancing in period two, there are no future refinancing decisions. Hence, Proposition 1 describes the manager's financing and investment decisions if she acquires new external finance.

To determine whether the manager refinances in period two we compare the total net benefit from acquiring external finance and investing it in physical capital to that from settling for the capital stock that can be financed internally, denoted by $\tilde{K}_3 = p^{-1}C_2$:

$$\begin{aligned} \mathcal{H}_2 = \quad & \beta\{-[r(D_3^*) - i][D_3^* - D_2] - [r(D_3^*) - r(D_2)]D_2 - (1+i)\mu\} \\ & + \beta\{[\Pi(K_3^*) - \Pi(\tilde{K}_3)] - p[K_3^* - \tilde{K}_3](i+\delta)\}. \end{aligned} \tag{5}$$

The two bracketed expressions capture the financial and real effects, respectively, of refinancing. In the financial sector, the increased stock of external finance is paid for, the cost of carrying the existing external finance increases, and the (compounded) fixed cost of refinancing is incurred. In the real sector, the firm enjoys revenue from a larger capital stock, but also pays for this investment.

The function $\mathcal{H}_2$ defines a threshold level of internal funds, $\hat{C}_2$, that triggers refinancing. As long as $C_2 \geq \hat{C}_2$, the manager refrains from refinancing. But when C_2 falls below $\hat{C}_2$, the capital stock that can be internally financed, $\tilde{K}_3$, has shrunk to the point where the marginal revenue product of capital is high enough to warrant incurring the fixed cost. This decision rule is summarized in Proposition 2.

Proposition 2: *The investment and financing decisions of the firm in period two can be characterized in terms of two regions of values of C_2 defined by the threshold $\hat{C}_2$.*

(1) When $C_2 < \hat{C}_2$, the manager increases external finance and invests optimally as described in Proposition 1.

(2) When $C_2 \geq \hat{C}_2$, the manager does not increase external finance. If C_2 is large enough to internally finance the capital stock that is optimal with external finance unchanged at D_2, then the manager invests optimally as described in Proposition 1.

Otherwise there is under-investment relative to the optimum without financial xenophobia.

According to Proposition 2, the contemporaneous refinancing cost does not affect the firm's behavior when internal funds fall below the threshold $\hat{C}_2$ or when they exceed the level that makes it possible to internally finance the capital stock that is optimal when external financing is unchanged at D_2. However, for intermediate levels of internal funds, the fixed financial adjustment cost introduces financial inertia and under-investment in capital. Finally, it is worth pointing out that if $\hat{C}_2 \leq C_2 < 0$, then the deficit is eliminated by selling capital.[8]

4.2 Period One

In the first period, the manager's decision problem is complicated by the specter of future costs of refinancing. The manager may be able to decrease the risk of incurring these costs by accumulating excess resources inside the firm. Such behavior is akin to saving precautionarily. As a result, both real and financial decision-making are distorted.

The risk of incurring the cost of refinancing in period two can be derived from the optimal refinancing policy described in Proposition 2: the cost will be incurred if and only if $C_2 < \hat{C}_2$. We map this condition into the space of realizations of the revenue shock, calling $\hat{z}_2$ the critical value of the shock that triggers refinancing. For all realizations of $z_2 < \hat{z}_2$, the firm must incur the cost of refinancing, so the probability of this event is equal to:

$$\int_{-\infty}^{\hat{z}_2} f(z_2)dz.$$

In Lemma 1, the marginal effects of the period one decision variables, D_2 and K_2, on the expected future cost of refinancing are derived using Leibnitz's Rule.

Lemma 1: *Define $\psi \equiv \Pi'(\tilde{K}_3) - \Pi'(K_3^*)$, where $\tilde{K}_3$ and K_3^* are evaluated at $z_2 = \hat{z}_2$.*

[8] Shleifer and Vishny (1992) study the trade-off between asset liquidation and the acquisition of external finance.

$$\begin{aligned}\frac{\partial \mathrm{E}[m(D_2, D_3^*)]}{\partial D_2} &= \mu f(\hat{z}_2)\left[\frac{\mathrm{d}\hat{z}_2}{\mathrm{d}D_2}\right] \\ &= -\mu f(\hat{z}_2)\left\{(1+i) - [r(D_2) + r'(D_2)D_2] - \frac{pr'(D_2)D_2}{\psi}\right\}\end{aligned} \tag{6}$$

$$\begin{aligned}\frac{\partial \mathrm{E}[m(D_2, D_3^*)]}{\partial K_2} &= \mu f(\hat{z}_2)\left[\frac{\mathrm{d}\hat{z}_2}{\mathrm{d}K_2}\right] \\ &= -\mu f(\hat{z}_2)\left\{\Pi'(K_2) - p(i+\delta)\right\}\end{aligned} \tag{7}$$

These two effects on the expected cost of refinancing are critical elements in the model, so we highlight the economic intuition behind them. The manager's decisions affect neither the magnitude of the refinancing cost, μ, nor the probability distribution of the revenue shocks, $f(z)$. The only remaining channel is through the threshold-level of the revenue shock that triggers refinancing in the subsequent period, $\hat{z}_2$.

An increase in external finance in period one has three effects on $\hat{z}_2$ in equation (6). First, additional external finance increases internal funds in period two by the face value of the added finance plus the return that it earns. This enables the firm to absorb a less favorable shock, thus decreasing the threshold that triggers refinancing. Second, additional external finance must be serviced, although not paid-in-full, which decreases internal funds and therefore increases $\hat{z}_2$. Finally, additional external finance increases the cost of servicing the existing stock of external finance in period two by $r'(D_2)D_2$. This effect increases $\hat{z}_2$ by making it less costly, and therefore more attractive, to refinance in period two.

An increase in the outgoing capital stock, K_2, has three effects on $\hat{z}_2$ in equation (7). First, an additional unit of capital generates revenue of $\Pi'(K_2)$ in period two which boosts internal funds and decreases $\hat{z}_2$. Second, buying capital in period one decreases internal funds in period two by $p(1+i)$, which increases $\hat{z}_2$. Finally, an additional unit of capital in period one increases the liquidation value of the existing capital stock in period two by $p(1-\delta)$. This means that a larger capital stock can be financed internally, which makes refinancing less urgent and decreases $\hat{z}_2$. Combining the latter two effects yields the standard rental cost of internally financed capital, $p(i+\delta)$.

The heart of the manager's decision problem in period one is the trade-off between future refinancing costs and direct effects on cash-flow. This comparison is captured by the following parameter, which measures the relative importance of the future refinancing cost in the manager's objective function:

$$\phi = \frac{\mu f(\hat{z}_2)}{1 + \mu f(\hat{z}_2)}.$$

The parameter ϕ lies between 0 and 1 and is strictly increasing in μ and in $f(\hat{z}_2)$. This makes it natural to interpret ϕ as a firm-specific parameter measuring the extent of management's financial xenophobia: the higher the fixed cost of accessing external finance, the higher is ϕ.

Proposition 3 and Corollary 1 describe the manager's optimal finance and investment policies in period one, which take into account the expected cost of future refinancing.

Proposition 3: *Suppose that the fixed cost of refinancing in period one is irrelevant either because it is sunk or because it was not incurred. The investment and financing decisions of the firm can be characterized in terms of two regions of values of C_1 defined by the threshold $\bar{C}_1$.*

(1) When $C_1 \le \bar{C}_1$, the firm holds external finance, but no liquidity. The optimal capital stock and external finance are given jointly by the first constraint (equation (3)), which holds with equality, and the following marginal condition:

$$\Pi'(K_2^*) = p[r(D_2^*) + r'(D_2^*)D_2^* + \delta] - p\phi\left[1 - \frac{pr'(D_2^*)D_2^*}{\psi}\right].$$

Compared to optimal investment without financial xenophobia, over-investment occurs when internal funds are sufficiently large to satisfy the following condition: $\psi > pr'(D_2^*)D_2^*$.

(2) When $C_1 > \bar{C}_1$, the firm holds both liquidity and external finance. The optimal capital stock and external finance are given jointly by the following two marginal conditions:

$$\Pi'(K_2^*) = p(i + \delta)$$

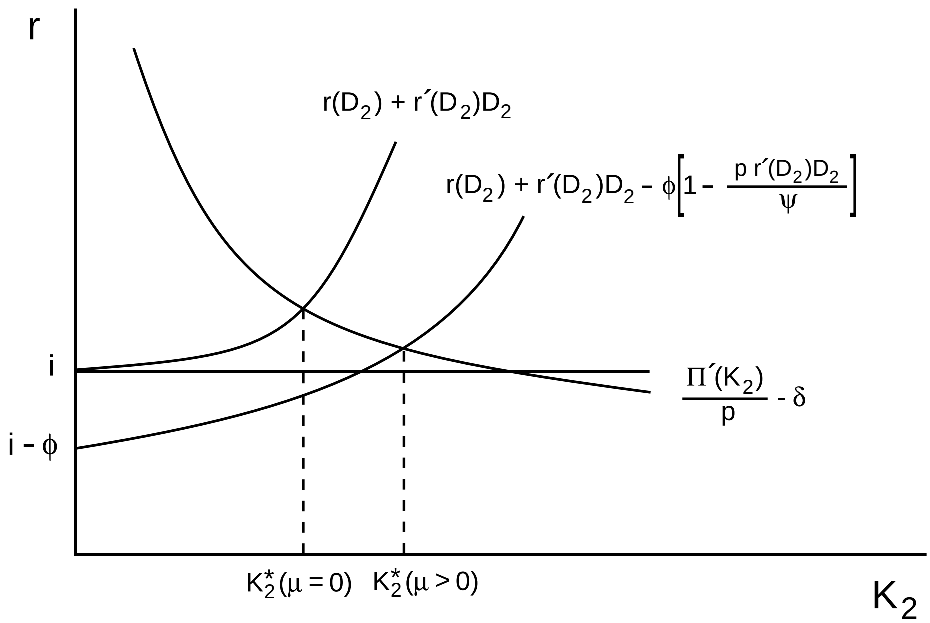

Figure 3: Optimal Investment and Financing Decisions With Financial Xenophobia: Holding No Liquidity

$$r(D_2^*) + r'(D_2^*)D_2^* + \phi\left[\frac{pr'(D_2^*)D_2^*}{\psi}\right] = i + \phi.$$

Investment is unaffected by financial xenophobia. The stock of liquidity is given as a residual by equation (1). $\bar{C}_1$ *is given by the first constraint (equation (3)) when it holds with equality.*

Corollary 1:

(1) $\bar{C}_1$ *is strictly decreasing in* ϕ *and approaches infinity as* ϕ *approaches zero.*

(2) *When* $C_1 \leq \bar{C}_1$*, the firm splits an additional dollar between capital investment and retirement of external finance.*

(3) *When* $C_1 > \bar{C}_1$*, neither investment nor financing is responsive to cash flow with the firm holding an additional dollar as liquidity.*

The manager's optimal decisions when $C_1 < \bar{C}_1$ are illustrated in Figure 3. Compared to the case of no financial xenophobia, the expected future cost of refinancing shifts the curve representing the net marginal cost of external funds, $r(D_2) + r'(D_2)D_2$, by

$\phi\left[1-\frac{pr'(D_2)D_2}{\psi}\right]$. This distortion term captures the effect of an additional dollar of external finance in period one on the firm's refinancing decision in period two: another dollar of resources is available, but part of the increased cost of external finance is sunk in period one, making refinancing in period two more attractive.

Whether there is over- or under-investment relative to the case without financial xenophobia depends on the sign of the distortion term. When C_1 is large enough, the distortion term is positive so the net marginal cost of external funds shifts down, resulting in over-investment. This is the case we depict in Figure 3. As C_1 falls, $pr'(D_2)D_2$ increases without bound, discouraging saving precautionarily in capital. Intuition therefore suggests that the firm may underinvest when internal funds are sufficiently low. However, we are unable to prove this in the general case because there is no closed-form solution for $\hat{z}_2$.

When $C_1 < \bar{C}_1$ and the firm is liquidity-constrained, both real and financial decisions are responsive to changes in the firm's cash position. An increase in internal funds is split between investment and repayment of external finance because the marginal benefit of liquidity is only i. Moreover, the firm's behavior is also responsive to changes in neoclassical fundamentals through the net marginal revenue product of capital.

Figure 4 illustrates what happens when C_1 reaches $\bar{C}_1$. At this point, internal funds (again labeled cash for shorthand) have driven down the amended marginal cost of external funds to the point where it is equal to the marginal benefit of holding idle liquidity. Notice that this happens while D_2 remains strictly positive since the marginal benefit of repaying external finance falls short of that of holding cash by ϕ when $D_2 = 0$. Therefore, for all $C_1 > \bar{C}_1$, liquidity dominates the retirement of external financing, so the firm will keep its stock of external finance fixed. Moreover, it will not adjust its capital stock either. When the firm starts to hold liquidity at $\bar{C}_1$, the opportunity cost of funds for capital investment, which can now be provided internally, becomes i, which is constant. Hence, both the firm's financing and investment are unresponsive to additional cash, which is simply added to the firm's holding of idle liquidity. However, neoclassical fundamentals still affect the firm's optimal investment and finance strategy.

To close the model, the value of the frictionless optimal decision derived in Proposition 3 must be compared to the fixed cost of refinancing in period one. To analyze

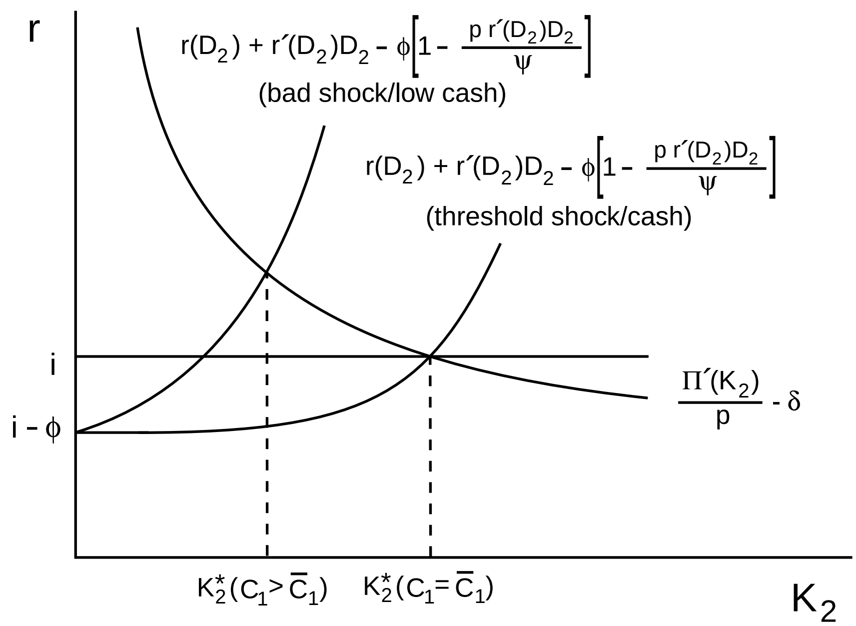

Figure 4: Optimal Investment and Financing Decisions With Financial Xenophobia: Holding Liquidity

this problem, we define the net benefit to refinancing in period one:

$$\mathcal{H}_1 = \beta\Big\{-[r(D_2^*) - i][D_2^* - D_1] - [r(D_2^*) - r(D_1)]D_1 - (1+i)\mu + \mu\int_{\hat{z}_2(D_2^*,K_2^*)}^{\hat{z}_2(D_1,\tilde{K}_2)} f(z)dz\Big\} + \beta\Big\{[\Pi(K_2^*) - \Pi(\tilde{K}_2)] - p[K_2^* - \tilde{K}_2](i+\delta)\Big\}. \quad (8)$$

The integration-term represents the benefit from a decreased risk of refinancing in the subsequent period. It is never optimal to refinance if the additional resources will be held as cash, i.e., $\mathcal{H}_1$ is strictly negative for all $C_1 \geq \bar{C}_1$. Moreover, $\mathcal{H}_1$ is strictly decreasing in internal funds, C_1, and therefore also in the revenue shock, z_1, and becomes strictly positive for sufficiently bad shocks. This allows us to conclude that there exists a unique threshold, $\hat{z}_1 < \bar{z}_1$, that triggers refinancing: if z_1 falls below $\hat{z}_1$, the manager chooses to refinance in period one, but refrains from doing so if z_1 exceeds this threshold.

Proposition 4: *The investment and financing decision of the firm in period one can be characterized in terms of two regions of values of C_1 defined by the threshold $\hat{C}_1 < \bar{C}_1$.*

(1) When $C_1 < \hat{C}_1$, the manager increases external finance and invests as described in Proposition 3.

(2) When $C_1 \geq \hat{C}_1$, the manager does not increase external finance. If C_1 is large enough to internally finance the optimal capital stock with external finance unchanged at D_1, then the manager invests as described in Proposition 3. Otherwise there is under-investment in capital relative to the optimal policy described in Proposition 3.

5 Discussion

Opler, Pinkowitz, Stulz, and Williamson (1999) present some stylized facts about liquidity holding and investment. First, most liquid assets are held by a small subset of firms (see also Schnure 1998). Second, firms generate their liquidity internally. Third, firms use liquidity as insurance against future adverse shocks rather than to fund investment or to repay external financial obligations. As a result, the investment and financial policies of firms with idle liquidity are unresponsive to contemporaneous shocks to internal funds.

The key predictions of our model are consistent with these stylized facts. We show that a firm may hold idle liquidity even though its financial return is inferior to that of repaying external finance. Absent financial xenophobia, other models do not generate this type of liquidity holding. As we demonstrated in our baseline model, a risk premium on external finance (stemming from, for example, adverse selection or moral hazard) generates liquidity holding only when all external financial obligations are paid-in-full.[9] Jensen's free-cash-flow model and the earlier literature on empire-building managers (see, e.g., Baumol 1959, Marris 1964, Williamson 1964) rationalize the hoarding of resources, but cannot explain why managers hold them as idle liquidity instead of investing them for their own benefit. Moreover, we show that financially xenophobic firms generate liquidity internally and use it as insurance, leaving optimal investment and financial policies unaffected by shocks to contemporaneous cash flow.

[9] Recall that the baseline model collapses to the standard neoclassical one when investment is internally financed. Since internal finance is empirically the dominant source of investment finance, this model therefore leaves no role for financing considerations in most investment decisions.

At the same time, it should be emphasized that our model is stripped of many important features. We deliberately assumed that there is no risk, time-to-build, or adjustment costs in the investment technology because these assumptions seem least likely to favor liquidity holding. The compromise inherent in this approach is that the predictions about the firm's optimal investment policy lack robustness. For example, risk and partial irreversibility can generate an option value to waiting to invest. This might be a source of underinvestment.[10]

In terms of the financial technology, one notable assumption is that the marginal cost of external finance is deterministic. Relaxing this assumption, however, is not sufficient to generate liquidity holding in the absence of financial xenophobia. As long as the stochastic cost of external finance exceeds the return to idle liquidity, it is strictly preferable to repay in the current period as much external finance as possible and, if need be, refinance tomorrow.[11]

A well-functioning market for corporate control might temper the financially xenophobic manager's desire to hold idle cash. The reason is that cash, which is an asset that is not firm-specific, makes the firm a more attractive target for takeovers. However, due to transaction costs, for example, the free-rider problem pointed out by Grossman and Hart (1980), the firm would in all likelihood have some room to hold cash (see, e.g., Nickell 1995, chapter 2). In addition, in our model the firms that hold cash are those which are successful. This connection should serve as an automatic partial takeover defense.

The central assumption of our model is that the manager incurs a fixed cost when she increases, but not when she decreases, outside financing. An important building block of a theoretical foundation for this financial friction is provided by Burkart, Gromb, and Panunzi (1997) (BGP), who argue that granting managers independence can be efficient because it gives them stronger incentives to contribute to the firm. BGP point out that shareholders can credibly commit not to interfere by owning small

[10]It is worth pointing out, however, that irreversibility distorts only the investment policy. It cannot generate liquidity holding by itself since paying back external finance remains strictly preferable in the absence of some other distortion like financial xenophobia.

[11]If the firm has multi-period financial obligations that specify a time-invariant marginal cost schedule, then it may make sense to hoard liquidity when funds are relatively cheap. It is, however, difficult to conceive why any financier would agree to such a financial contract since it generates an expected loss.

stakes in the firm. However, what BGP do not consider is that the temptation to interfere may be stronger in certain circumstances. In particular, the empirical evidence we discussed in the introduction suggests that seeking additional external finance makes the firm more susceptible to direct control by outsiders. In these circumstances, the run-of-the-mill commitment devices emphasized by BGP may not suffice. Therefore, to avoid such break-down situations, insiders and outsiders should agree to grant the manager partial financial independence. Access to internal finance appears to be an attractive way to achieve this end since internal cash flow is correlated with the efficient management of the firm.

The idea that productive arrangements are particularly fragile in some economic circumstances is emphasized by Ramey and Watson (1997). They study employment relationships under the assumption that both employer and employee can engage in opportunistic behavior. Their perspective reinforces our view that corporate outsiders pose a threat to the contributions of the insiders as well as the other way around. den Haan, Ramey, and Watson (1999) build on this idea, showing that liquidity shocks can trigger inefficient severance of lending relationships. They provide a convincing argument that firms suffer when they are dependent on external finance. However, in den Haan et al. (1999) firms are passive as they cannot avoid this cost. In our model, managers actively seek financial independence to avoid the threat posed by outside financiers.

Our hypothesis about financial friction is also related to the literature on how financial contracts can help realign the interests of managers and their outside constituencies. Much of the recent research on financial contracts has focused on the control properties of financial contracts. From this perspective, the defining feature of debt is that it allows for a transfer of control from the manager to outside financiers in some circumstances, namely bankruptcy, but not in others.[12] The manager in our model is not afraid of bankruptcy in the normal sense of the word, but rather of losing some of her decision-making authority when she is forced to refinance; refinancing constitutes a partial, not full, transfer of control because it triggers a renegotiation between the manager and the outside financiers. This type of state-contingent renegotiation of

[12] Aghion and Bolton (1992) show that a debt contract that transfers control from the insiders to the lender in bankruptcy is optimal when short-term returns are a good signal of the firm's long-term prospects. For surveys of the financial contracting literature, see Hart (1995) and Harris and Raviv (1992).

financial contracts has been studied by Berglöf and von Thadden (1994) and Hart and Moore (1994, 1998), in particular with respect to how this flexibility *ex post* may hurt the firm's ability to precommit *ex ante* to repaying its financiers. Our idea is similar, except it concerns the opposite problem: renegotiation hampers the firm's financiers from credibly promising the manager to let her reap the benefits from her firm-specific investments.

Turning to the investment literature, Gomes (1998) analyzes investment decisions under uncertainty, but restricts firms to using only current period profits or external funds to finance their investment. By assuming that all of the firm's internal funds are flushed out of it at the end of each period, Gomes allows no meaningful role for internal finance through the retention of profits. The study closest in spirit to ours is Gross (1995). In both models, the firm's financial history determines the effect, if any, of financial frictions on its investment and financing decisions. However, the economics of Gross' analysis is quite different from that of ours. First, Gross adapts a buffer-stock model of consumption to study investment. Consequently, the firm may precautionarily save in cash in an attempt to avoid bankruptcy. This motive is balanced, however, by an agency problem that makes it desirable for shareholders to extract resources from the firm through dividends. Second, in Gross' model capital is a risky asset, which is why the firm underinvests and holds cash as insurance against bankruptcy. Finally, Gross' firm, like the firm in our baseline model, cannot simultaneously hold liquidity and external finance. In Gross' model, cash is nothing but negative external finance; in ours, using cash to repay external finance exposes the firm to the vagaries of external financiers.

6 Conclusion

There is a wealth of evidence to suggest that financing has important effects on investment. This makes it important to explicitly model how different types of financial frictions affect investment and financing over time. We have highlighted an empirically plausible friction: that managers suffer a fixed cost when they seek additional financing. Modeling financial xenophobia in this way generates two particularly interesting results. First, we show that the financially xenophobic manager may choose to hold liquidity and external finance simultaneously, a stylized fact that is not easily explained by existing models. Second, in this situation the financially xenophobic manager channels an extra dollar of cash into idle liquidity even though she has the seemingly superior alternative of repaying external finance.

The model is highly stylized. First, it lacks a model of the conflict of interest between the manager and outside financiers that generates financial xenophobia. Explicit consideration of this may reveal a more complex structure than the fixed cost that we assume. Second, we have assumed that the revenue shock is iid and additive. Relaxing the iid assumption may help in fitting data, but it is unlikely to change the qualitative conclusions; relaxing the additivity assumption will affect the character of the model. When shocks are non-additive capital becomes risky, which can dramatically change its precautionary savings benefit. The precise effects of this modification are difficult to infer based on the simple model studied here. Finally, the model has rudimentary dynamics. The manager's decisions are affected by concern for the future in the first period only. More generally, it may be possible to extend our model to an infinite horizon framework, where we conjecture that the optimal policy would closely resemble what we derived for period one. This extension and the model of the underlying hold-up problem are our top priorities for future research.

A Proofs of Propositions

Proof of Proposition 1: When there is no financial xenophobia ($\mu = 0$) the first-order conditions for the problem defined by equations (2), (3), and (4) are:

$$-p + \beta[\Pi'(K^*_{t+1}) + p(1-\delta)] - \lambda_1 = 0 \tag{9}$$

$$1 - \beta[1 + r(D^*_{t+1}) + r'(D^*_{t+1})D^*_{t+1}] + \lambda_1 p^{-1} + \lambda_2 = 0. \tag{10}$$

When $D_{t+1} > 0$, $\lambda_2 = 0$. In this case, we can solve for λ_1 using the first-order condition for external finance (equation (10)):

$$\begin{aligned} \lambda_1 &= p\beta[1 + r(D^*_{t+1}) + r'(D^*_{t+1})D^*_{t+1} - (1+i)] \\ &= p\beta[r(D^*_{t+1}) + r'(D^*_{t+1})D^*_{t+1} - i] > 0. \end{aligned} \tag{11}$$

Since $\lambda_1 > 0$, the first constraint (equation (3)) holds with equality, which means that the firm holds no liquidity. K^*_{t+1} and D^*_{t+1} are determined jointly by the first constraint (equation (3)) and the following marginal optimality condition, which is derived by substituting the solution for λ_1 (equation (11)) into equation (9):

$$\begin{aligned} &-p + \beta[\Pi'(K^*_{t+1}) + p(1-\delta)] = p\beta[r(D^*_{t+1}) + r'(D^*_{t+1})D^*_{t+1} - i] \\ &\Pi'(K^*_{t+1}) = p[r(D^*_{t+1}) + r'(D^*_{t+1})D^*_{t+1} + \delta]. \end{aligned}$$

When $D_{t+1} = 0$, $r(D_{t+1}) = i$ and $r'(D_{t+1})D_{t+1} = 0$. In this case, we can solve for λ_1 and λ_2 using the first-order condition for external finance (equation (10)):

$$\begin{aligned} \lambda_1 p^{-1} + \lambda_2 &= p\beta[1 + r(D^*_{t+1}) + r'(D^*_{t+1})D^*_{t+1} - (1+i)] \\ &= p\beta[(1+i) - (1+i)] = 0. \end{aligned}$$

The multipliers must be non-negative so $\lambda_1 = \lambda_2 = 0$. Since $\lambda_1 = 0$, we can solve for the optimal capital stock using equation (9):

$$\begin{aligned} &-p + \beta[\Pi'(K^*_{t+1}) + p(1-\delta)] = 0 \Leftrightarrow \\ &\Pi'(K^*_{t+1}) = p(i+\delta). \end{aligned}$$

The firm's liquidity holding is determined as a residual using the first constraint (equation (3)). ■

Proof of Proposition 2: Differentiate $\mathcal{H}_2$, defined in equation (5), with respect to C_2.

$$\begin{aligned}
\frac{\partial \mathcal{H}_2}{\partial C_2} &= \beta\Big\{\Pi'(K_3^*)\frac{\partial K_3^*}{\partial C_2} - \Pi'(\tilde{K}_3)\frac{\partial \tilde{K}_3}{\partial C_2} - p\Big[\frac{\partial K_3^*}{\partial C_2} - \frac{\partial \tilde{K}_3}{\partial C_2}\Big][r(D_2)+\delta] \\
&\quad -[r(D_3^*) - r(D_2)]\frac{\partial D_3^*}{\partial C_2} - r'(D_3^*)D_3^*\frac{\partial D_3^*}{\partial C_2}\Big\} \\
&= \beta\Big\{\Big\{\Pi'(K_3^*) - p[r(D_2)+\delta]\Big\}\frac{\partial K_3^*}{\partial C_2} - \Big\{\Pi'(\tilde{K}_3) - p[r(D_2)+\delta]\Big\}\frac{\partial \tilde{K}_3}{\partial C_2} \\
&\quad -[r(D_3^*) + r'(D_3^*)D_3^* - r(D_2)]\frac{\partial D_3^*}{\partial C_2}\Big\} \\
&= \beta\Big\{\Big\{\Pi'(K_3^*) - p[r(D_2)+\delta]\Big\}\frac{\partial K_3^*}{\partial C_2} - \Big\{\Pi'(\tilde{K}_3) - p[r(D_2)+\delta]\Big\}\frac{\partial \tilde{K}_3}{\partial C_2} \\
&\quad -[r(D_3^*) + r'(D_3^*)D_3^* - r(D_2)]\Big(p\frac{\partial K_3^*}{\partial C_2} - 1\Big)\Big\} \\
&= \beta\Big\{\Big\{\Pi'(K_3^*) - p[r(D_3^*) + r'(D_3^*)D_3^* + \delta]\Big\}\frac{\partial K_3^*}{\partial C_2} \\
&\quad -p^{-1}\Big\{\Pi'(\tilde{K}_3) - p[r(D_3^*) + r'(D_3^*)D_3^* + \delta]\Big\}\Big\} \\
&= -\beta p^{-1}\Big\{\Pi'(\tilde{K}_3) - p[r(D_3^*) + r'(D_3^*)D_3^* + \delta]\Big\} \\
&= -\beta p^{-1}[\Pi'(\tilde{K}_3) - \Pi'(K_3^*)] < 0.
\end{aligned}$$

The capital stock that can be financed internally, $\tilde{K}_3$, increases with C_2. It reaches its minimum of zero when $C_2 \le -p(1-\delta)K_2$, which makes $\mathcal{H}_2(C_2) = \infty$. Moreover, for a sufficiently large C_2, $\tilde{K}_3 = K_3^*$ and $D_3^* = D_2$, which implies that $\mathcal{H}_2(C_2) = -(1+i)\mu < 0$. It therefore follows from the Intermediate Value Theorem that there exists a unique $\hat{C}_2$ such that $\mathcal{H}_2(\hat{C}_2) = 0$.

There are two cases to consider:

(1) $C_2 < \hat{C}_2$. In this case, the firm refinances. The fixed cost of refinancing is sunk so Proposition 1 describes the optimal behavior when $D_3^* > 0$.

(2) $C_2 \ge \hat{C}_2$. In this case, the optimal behavior depends on the realization of C_2. When C_2 is sufficient to finance the capital stock that is optimal when external finance is

equal to D_2, Proposition 1 describes the optimal behavior. When C_2 is insufficient to finance this optimal capital stock, the firm invests as much as possible, holds no liquidity, and external finance remains at D_2. ■

Proof of Lemma 1:

Since both μ and the density function are independent of the period-one decision variables, Leibnitz's rule implies that $\frac{\partial \mathrm{E}[m(D_2,D_3^*)]}{\partial D_2} = \mu f(\hat{z}_2)\left[\frac{\mathrm{d}\hat{z}_2}{\mathrm{d}D_2}\right]$. The same argument applies to the derivative with respect to K_2.

Next, differentiate $\mathcal{H}_2$ with respect to z_2, K_2, and D_2.

$$
\begin{aligned}
\frac{\mathrm{d}\mathcal{H}_2}{\mathrm{d}z_2} &= \frac{\partial\mathcal{H}_2}{\partial C_2}\frac{\partial C_2}{\partial z_2} = \frac{\partial\mathcal{H}_2}{\partial C_2} = -\beta p^{-1}[\Pi'(\tilde{K}_3) - \Pi'(K_3^*)] = -\beta p^{-1}\psi. \\
\frac{\mathrm{d}\mathcal{H}_2}{\mathrm{d}D_2} &= \beta\Big\{\Pi'(K_3^*)\frac{\partial K_3^*}{\partial C_2}\frac{\partial C_2}{\partial D_2} - \Pi'(\tilde{K}_3)\frac{\partial \tilde{K}_3}{\partial C_2}\frac{\partial C_2}{\partial D_2} - p\left[\frac{\partial K_3^*}{\partial C_2}\frac{\partial C_2}{\partial D_2} - \frac{\partial \tilde{K}_3}{\partial C_2}\frac{\partial C_2}{\partial D_2}\right][r(D_2)+\delta] \\
&\quad -p[K_3^* - \tilde{K}_3]r'(D_2) - [r(D_3^*) - r(D_2)]\frac{\partial D_3^*}{\partial C_2}\frac{\partial C_2}{\partial D_2} \\
&\quad -r'(D_3^*)D_3^*\frac{\partial D_3^*}{\partial C_2}\frac{\partial C_2}{\partial D_2} + r'(D_2)D_3^*\Big\} \\
&= \frac{\partial\mathcal{H}_2}{\partial C_2}\frac{\partial C_2}{\partial D_2} + \beta r'(D_2)D_2 \\
&= \frac{\partial\mathcal{H}_2}{\partial C_2}\Big\{(1+i) - [r(D_2) + r'(D_2)D_2]\Big\} + \beta r'(D_2)D_2. \\
\frac{\mathrm{d}\mathcal{H}_2}{\mathrm{d}K_2} &= \beta\Big\{\Pi'(K_3^*)\frac{\partial K_3^*}{\partial C_2}\frac{\partial C_2}{\partial K_2} - \Pi'(\tilde{K}_3)\left[\frac{\partial \tilde{K}_3}{\partial C_2}\frac{\partial C_2}{\partial K_2}\right] - [r(D_3^*) - r(D_2)]\frac{\partial D_3^*}{\partial C_2}\frac{\partial C_2}{\partial K_2} \\
&\quad -p\left\{\frac{\partial K_3^*}{\partial C_2}\frac{\partial C_2}{\partial K_2} - \left[\frac{\partial \tilde{K}_3}{\partial C_2}\frac{\partial C_2}{\partial K_2}\right]\right\}[r(D_2)+\delta] - r'(D_3^*)D_3^*\frac{\partial D_3^*}{\partial C_2}\frac{\partial C_2}{\partial K_2}\Big\} \\
&= \frac{\partial\mathcal{H}_2}{\partial C_2}\frac{\partial C_2}{\partial K_2} = \frac{\partial\mathcal{H}_2}{\partial C_2}\Big[\Pi'(K_2) - p(1+i) + p(1-\delta)\Big] \\
&= \frac{\partial\mathcal{H}_2}{\partial C_2}\Big[\Pi'(K_2) - p(i+\delta)\Big].
\end{aligned}
$$

We use the Implicit Function Theorem to complete the proof:

$$
\begin{aligned}
\frac{\mathrm{d}\hat{z}_2}{\mathrm{d}D_2} = -\left.\frac{\frac{\mathrm{d}\mathcal{H}_2}{\mathrm{d}D_2}}{\frac{\mathrm{d}\mathcal{H}_2}{\mathrm{d}z_2}}\right|_{z_2=\hat{z}_2} &= -\frac{\frac{\partial\mathcal{H}_2}{\partial C_2}\Big\{(1+i) - [r(D_2)+r'(D_2)D_2]\Big\} + \beta r'(D_2)D_2}{\frac{\partial\mathcal{H}_2}{\partial C_2}} \\
&= -\Big\{(1+i) - [r(D_2)+r'(D_2)D_2] - \frac{pr'(D_2)D_2}{\psi}\Big\}.
\end{aligned}
$$

$$\frac{\mathrm{d}\hat{z}_2}{\mathrm{d}K_2} = -\left.\frac{\frac{\mathrm{d}\mathcal{H}_2}{\mathrm{d}K_2}}{\frac{\mathrm{d}\mathcal{H}_2}{\mathrm{d}z_2}}\right|_{z_2=\hat{z}_2} = -\frac{\frac{\partial\mathcal{H}_2}{\partial C_2}\Big\{\Pi'(K_2) - p(i+\delta)\Big\}}{\frac{\partial\mathcal{H}_2}{\partial C_2}}$$

$$= -\Big\{\Pi'(K_2) - p(i+\delta)\Big\}. \qquad \blacksquare$$

Proof of Proposition 3: When there is financial xenophobia ($\mu > 0$) the first-order conditions for the problem defined by equations (2), (3), and (4) in period one are:

$$-p + \beta\left\{\Pi'(K_2^*) + p(1-\delta) - \frac{\partial \mathrm{E}[m(D_2^*, D_3^*)]}{\partial K_2^*}\right\} - \lambda_1 = 0 \tag{12}$$

$$1 - \beta\left\{1 + r(D_2^*) + r'(D_2^*)D_2^* + \frac{\partial \mathrm{E}[m(D_2^*, D_3^*)]}{\partial D_2^*}\right\} + \lambda_1 p^{-1} + \lambda_2 = 0. \tag{13}$$

There are three cases to consider.

When $D_2 = 0$, $\lambda_1 \geq 0$ and $\lambda_2 \geq 0$. In this case, we can solve for λ_1 and λ_2 using the first-order condition for external finance (equation (13)):

$$\begin{aligned}
p^{-1}\lambda_1 + \lambda_2 &= \beta\left\{r(D_2^*) + r'(D_2^*)D_2^* - i + \frac{\partial \mathrm{E}[m(D_2^*, D_3^*)]}{\partial D_2^*}\right\} \\
&= \beta\frac{\partial \mathrm{E}[m(D_2^*, D_3^*)]}{\partial D_2^*} \\
&= -\beta\mu f(\hat{z}_2) < 0.
\end{aligned}$$

This is a contradiction, which rules out the possibility that the optimal stock of external finance is equal to zero.

When $L_2 > 0$ and $D_2 > 0$, $\lambda_1 = 0$ and $\lambda_2 = 0$. The optimal capital stock and external finance is given jointly by the two first-order conditions. Start with the first-order condition with respect to capital (equation (12)):

$$\beta\left\{\Pi'(K_2^*) - p(i+\delta) - \frac{\partial \mathrm{E}[m(D_2^*, D_3^*)]}{\partial K_2^*}\right\} = 0 \Leftrightarrow$$

$$\Pi'(K_2^*) = p(i+\delta) - \mu f(\hat{z}_2)\Big\{\Pi'(K_2) - p(i+\delta)\Big\} \Leftrightarrow$$

$$\Pi'(K_2^*) = p(i+\delta) \tag{14}$$

Next, consider the first order condition with respect to external finance (equation (13)):

$$r(D_2^*) + r'(D_2^*)D_2^* - i + \frac{\partial \mathrm{E}[m(D_2^*, D_3^*)]}{\partial D_2^*} = 0$$
$$r(D_2^*) + r'(D_2^*)D_2^* - i - \mu f(\hat{z}_2)\left\{(1+i) - [r(D_2^*) + r'(D_2^*)D_2^*] - \frac{pr'(D_2^*)D_2^*}{\psi}\right\} = 0$$

$$r(D_2^*) + r'(D_2^*)D_2^* + \phi\left[\frac{pr'(D_2^*)D_2^*}{\psi}\right] = i + \phi.$$

The firm's liquidity holding is determined as a residual using the first constraint (equation (3)).

When $L_2 = 0$ and $D_2 > 0$, $\lambda_1 \geq 0$ and $\lambda_2 = 0$. Start by solving for λ_1 using the first order condition for external finance (equation (13)):

$$\lambda_1 = p\beta\left\{r(D_2^*) + r'(D_2^*)D_2^* - i + \frac{\partial \mathrm{E}[m(D_2^*, D_3^*)]}{\partial D_2^*}\right\} > 0. \tag{15}$$

Since $\lambda_1 > 0$, the first constraint (equation (3)) holds with equality, which means that the firm holds no liquidity. K_2^* and D_2^* are determined jointly by the first constraint (equation (3)) and the following marginal optimality condition, which is derived by substituting the solution for λ_1 (equation (15)) into equation (12):

$$\beta\left\{\Pi'(K_2^*) - p(i+\delta) - \frac{\partial \mathrm{E}[m(D_2^*, D_3^*)]}{\partial K_2^*}\right\} -$$
$$p\beta\left\{r(D_2^*) + r'(D_2^*)D_2^* - i + \frac{\partial \mathrm{E}[m(D_2^*, D_3^*)]}{\partial D_2^*}\right\} = 0$$

$$\begin{aligned}
\Pi'(K_2^*) = \quad & p[r(D_2^*) + r'(D_2^*)D_2^* + \delta] + p\frac{\partial \mathrm{E}[m(D_2^*, D_3^*)]}{\partial D_2^*} + \frac{\partial \mathrm{E}[m(D_2^*, D_3^*)]}{\partial K_2^*} \\
\Pi'(K_2^*) = \quad & p[r(D_2^*) + r'(D_2^*)D_2^* + \delta] - p\mu f(\hat{z}_2)\left\{(1+i) - [r(D_2^*) + r'(D_2^*)D_2^*]\right. \\
& \left. - \frac{pr'(D_2^*)D_2^*}{\psi} + \Pi'(K_2^*)p^{-1} - (i+\delta)\right\} \\
\Pi'(K_2^*) = \quad & p[r(D_2^*) + r'(D_2^*)D_2^* + \delta] - p\phi\left[1 - \frac{pr'(D_2^*)D_2^*}{\psi}\right].
\end{aligned}$$

There is overinvestment when $\psi > pr'(D_2^*)D_2^*$. This inequality is satisfied at $\bar{C}_1$ since equation (14) implies that at $\bar{C}_1$, $\Pi'(K_2^*) = p(i+\delta) < p[r(D_2^*) + r'(D_2^*)D_2^* + \delta]$. The fact that the left-hand side is continuous in C_1 therefore establishes that the distortion inequality is also satisfied when C_1 is sufficiently close to $\bar{C}_1$. ■

Proof of Corollary 1: (1) $\bar{C}_1$ is implicitly defined by the following equation:

$$\mathcal{G}_1 = r(D_2^*(\bar{C}_1)) + r'(D_2^*(\bar{C}_1))D_2^*(\bar{C}_1) + +\phi\left[\frac{pr'(D_2^*(\bar{C}_1))D_2^*(\bar{C}_1)}{\psi}\right] - (i+\phi) = 0.$$

Differentiate $\mathcal{G}_1$ with respect to C_1 and with respect to ϕ:

$$\begin{aligned}
\frac{\mathrm{d}\mathcal{G}_1}{\mathrm{d}C_1} &= 2r'(D_2^*)\frac{\partial D_2^*}{\partial C_1} + r''(D_2^*)D_2^*\frac{\partial D_2^*}{\partial C_1} + p\left(\frac{\phi}{\psi}\right)\left\{r'(D_2^*)\frac{\partial D_2^*}{\partial C_1} + r''(D_2^*)D_2^*\frac{\partial D_2^*}{\partial C_1}\right\} \\
&= \left\{r'(D_2^*) + \left[1 + p\left(\frac{\phi}{\psi}\right)\right]\left[r'(D_2^*) + r''(D_2^*)D_2^*\right]\right\}\frac{\partial D_2^*}{\partial C_1} < 0. \\
\frac{\mathrm{d}\mathcal{G}_1}{\mathrm{d}\phi} &= \frac{pr'(D_2^*)D_2^*}{\psi} - 1.
\end{aligned}$$

We use the Implicit Function Theorem to complete the proof:

$$\frac{\mathrm{d}\bar{C}_1}{\mathrm{d}\phi} = -\left.\frac{\frac{\mathrm{d}\mathcal{G}_1}{\mathrm{d}\phi}}{\frac{\mathrm{d}\mathcal{G}_1}{\mathrm{d}C_1}}\right|_{C_1=\bar{C}_1} = \frac{\partial\mathcal{G}_1}{\partial\phi}\left[-\left(\frac{\partial\mathcal{G}_1}{\partial C_1}\right)^{-1}\right].$$

This derivative takes the same sign as $\frac{\partial\mathcal{G}_1}{\partial\phi}$ which is negative at $\bar{C}_1$:

$$\begin{gathered}
p(i+\delta) = \Pi'(K_1^*(\bar{C}_1)) = p[r(D_2^*) + r'(D_2^*)D_2^* + \delta] - p\phi\left[1 - \frac{pr'(D_2^*)D_2^*}{\psi}\right] \Leftrightarrow \\
\phi\left[1 - \frac{pr'(D_2^*)D_2^*}{\psi}\right] = r(D_2^*) + r'(D_2^*)D_2^* - i > 0 \Rightarrow \\
\frac{pr'(D_2^*)D_2^*}{\psi} - 1 < 0.
\end{gathered}$$

(2) This statement follows directly from the proof of Proposition 3.

(3) This statement follows from the fact that optimal solutions for external finance and capital are independent of C_1 when $C_1 > \bar{C}_1$. ■

Proof of Proposition 4: If $C_1 \geq \bar{C}_1$, then $\tilde{K}_2 = K_2^*$, which implies that

$$\begin{aligned}
\mathcal{H}_1 = \quad & \beta\Big\{-[r(D_2^*) - i][D_2^* - D_1] - [r(D_2^*) - r(D_1)]D_1 - (1+i)\mu + \mu\int_{\hat{z}_2(D_2^*,K_2^*)}^{\hat{z}_2(D_1,\tilde{K}_2)} f(z)dz\Big\} \\
& < -\beta\Big\{[r(D_2^*) - i][D_2^* - D_1] + [r(D_2^*) - r(D_1)]D_1 + \mu i\Big\} < 0.
\end{aligned}$$

Moreover, for all $C_1 \leq -p(1-\delta)K_1$, $\tilde{K}_2 = 0$ making $\mathcal{H}_1 = \infty$. Therefore, the statement follows from the Intermediate Value Theorem if $\mathcal{H}_1$ is strictly decreasing in C_1 for all $C_1 \in (-p(1-\delta)K_1, \bar{C}_1)$.

Differentiate $\mathcal{H}_1$ with respect to C_1

$$\begin{aligned}
\frac{\partial \mathcal{H}_1}{\partial C_1} \quad = \quad & \beta\Big\{\Pi'(K_2^*)\frac{\partial K_2^*}{\partial C_1} - \Pi'(\tilde{K}_2)\frac{\partial \tilde{K}_2}{\partial C_1} - p\Big[\frac{\partial K_2^*}{\partial C_1} - \frac{\partial \tilde{K}_2}{\partial C_1}\Big](i+\delta) - [r(D_2^*) - i]\frac{\partial D_2^*}{\partial C_1} \\
& -r'(D_2^*)D_2^*\frac{\partial D_2^*}{\partial C_1} - \mu f(\hat{z}_2)\Big[\frac{\mathrm{d}\hat{z}_2}{\mathrm{d}D_2^*}\frac{\partial D_2^*}{\partial C_1} + \frac{\mathrm{d}\hat{z}_2}{\mathrm{d}K_2^*}\frac{\partial K_2^*}{\partial C_1}\Big] + \mu f(\hat{z}_2)\Big[\frac{\mathrm{d}\hat{z}_2}{\mathrm{d}\tilde{K}_2}\frac{\partial \tilde{K}_2}{\partial C_1}\Big]\Big\} \\
= \quad & \beta\Big\{\Big[\Pi'(K_2^*) - p(i+\delta)\Big]\frac{\partial K_2^*}{\partial C_1} - \Big[\Pi'(\tilde{K}_3) - p(i+\delta)\Big]\frac{\partial \tilde{K}_2}{\partial C_1} \\
& -[r(D_2^*) + r'(D_2^*)D_2^* - i]\Big(p\frac{\partial K_2^*}{\partial C_1} - 1\Big) - \mu f(\hat{z}_2)\Big[\frac{\mathrm{d}\hat{z}_2}{\mathrm{d}D_2^*}\Big(p\frac{\partial K_2^*}{\partial C_1} - 1\Big)\Big] \\
& -\mu f(\hat{z}_2)\Big[\frac{\mathrm{d}\hat{z}_2}{\mathrm{d}K_2^*}\frac{\partial K_2^*}{\partial C_1}\Big] + \mu f(\hat{z}_2)\Big[\frac{\mathrm{d}\hat{z}_2}{\mathrm{d}\tilde{K}_2}\frac{\partial \tilde{K}_2}{\partial C_1}\Big]\Big\} \\
= \quad & \beta\Big\{\Big\{\Pi'(K_2^*) - p[r(D_2^*) + r'(D_2^*)D_2^* + \delta] - \mu f(\hat{z}_2)\Big[\frac{\mathrm{d}\hat{z}_2}{\mathrm{d}D_2^*}p + \frac{\mathrm{d}\hat{z}_2}{\mathrm{d}K_2^*}\Big]\Big\}\frac{\partial K_2^*}{\partial C_1} \\
& -\Big\{[\Pi'(\tilde{K}_2) - p(i+\delta)]p^{-1} - [r(D_2^*) + r'(D_2^*)D_2^* - i] \\
& -\mu f(\hat{z}_2)\Big[\frac{\mathrm{d}\hat{z}_2}{\mathrm{d}D_2^*} + \frac{\mathrm{d}\hat{z}_2}{\mathrm{d}\tilde{K}_2}p^{-1}\Big]\Big\}\Big\}.
\end{aligned}$$

Proposition 3 establishes that the first bracketed expression following the last equality is equal to zero. Hence,

$$\begin{aligned}
\frac{\partial \mathcal{H}_1}{\partial C_1} \quad = \quad & -\beta p^{-1}\Big\{\Pi'(\tilde{K}_2) - p[r(D_2^*) + r'(D_2^*)D_2^* + \delta] - \mu f(\hat{z}_2)\Big[\frac{\mathrm{d}\hat{z}_2}{\mathrm{d}D_2^*}p + \frac{\mathrm{d}\hat{z}_2}{\mathrm{d}\tilde{K}_2}\Big]\Big\} \\
= \quad & -\beta p^{-1}\Big\{\Pi'(\tilde{K}_2) - p[r(D_2^*) + r'(D_2^*)D_2^* + \delta] - \mu f(\hat{z}_2)\Big[\frac{\mathrm{d}\hat{z}_2}{\mathrm{d}D_2^*}p + \frac{\mathrm{d}\hat{z}_2}{\mathrm{d}K_2^*}\Big]\Big\} \\
& -\beta p^{-1}\Big\{\frac{\mathrm{d}\hat{z}_2}{\mathrm{d}K_2^*} - \frac{\mathrm{d}\hat{z}_2}{\mathrm{d}\tilde{K}_2}\Big\}
\end{aligned}$$

$$= \quad -\beta p^{-1}[\Pi'(\tilde{K}_2) - \Pi'(K_2^*)] - \beta p^{-1}\left\{\frac{\mathrm{d}\hat{z}_2}{\mathrm{d}K_2^*} - \frac{\mathrm{d}\hat{z}_2}{\mathrm{d}\tilde{K}_2}\right\} < -\beta p^{-1}\left\{\frac{\mathrm{d}\hat{z}_2}{\mathrm{d}K_2^*} - \frac{\mathrm{d}\hat{z}_2}{\mathrm{d}\tilde{K}_2}\right\}.$$

It therefore suffices to establish that the bracketed expression on the right-hand side of the last inequality is positive.

$$\begin{aligned} \frac{\mathrm{d}\hat{z}_2}{\mathrm{d}K_2^*} - \frac{\mathrm{d}\hat{z}_2}{\mathrm{d}\tilde{K}_2} &= -\left\{\Pi'(K_2^*) - p(i+\delta)\right\} + \left\{\Pi'(\tilde{K}_2) - p(i+\delta)\right\} \\ &= \Pi'(\tilde{K}_2) - \Pi'(K_2^*) > 0. \end{aligned}$$

■

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